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Wetting and Smoke Knockdown Characteristics of Surfactant Solutions

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Ninety surfactants of various types (anionic, cationic and nonionic) were screened for their ability to wet smoke produced by burning JP-5 fuel. The smoke was drawn through a gas sampling scrubber containing the solution of the surfactant in either distilled or salt water. A visual rating was given on the ability of the surfactant solution to wet the smoke particles. Seventeen surfactants were found to exhibit superior wetting characteristics for JP-5 smoke. The surfactants were also evaluated for their ability to knock down JP-5 smoke in a small chamber.

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CONTENTS

WETTING AND SMOKE KNOCKDOWN CHARACTERISTICS OF SURFACTANT SOLUTIONS

INTRODUCTION

Smoke is a major deterrent to fire fighting, particularly aboard ship where the passageways soon become filled with dense, black smoke making it extremely difficult for fire fighters to locate the fire. As part of an overall program to reduce the effects of smoke in shipboard fires, the use of surfactant solutions in the form of aerosol sprays to knock down smoke is being investigated. This report summarizes the initial phase of that investigation.

EXPERIMENTAL PROCEDURE

Smoke Knockdown Studies

The apparatus used to evaluate the ability of surfactant solutions to wet or to knock down smoke particles is shown in Figure 1. The apparatus consists of a 48x20x28 cm (lxwxh) plexiglass chamber connected to a smoke source via 10 cm galvanized ducting. Smoke generated by burning JP-5 fuel on a wick is drawn through the chamber by the slight negative pressure from the exhaust hood. A damper located in the exhaust pipe is used to regulate the smoke density in the chamber. A Spectra Physics, Model 1.32, He-Ne Laser (6800A) with a beam expander monitors the smoke density. The laser is equipped with a narrow band filter to eliminate the necessity of darkening the room during testing. The laser output is detected by a P 121 photomultiplier tube. A Keithley Electrometer, Model 610B, and a Keithley Recorder, Model 370, are used to follow the photomultiplier current.

Prior to the smoke knockdown studies, the laser is turned on and the photomultiplier current established for a clean box situation. Then the fire is ignited and the photomultiplier response monitored as the box becomes filled with smoke. The surfactant solution is then injected axially into the smoke stream in the form of an aerosol mist through the port shown in Figure 2. A de Vilbiss atomizer equipped with a 450 cc reservoir is used to generate the mist.

Note: Manuscript submitted January 21, 1977.

Wetting Studies

For the wetting studies smoke is drawn through a sampling scrubber (Figure 2) containing a 2% solution of the surfactant for three minutes. The solution is transferred to a test tube and a visual rating given to the wetting ability of the surfactant. A (-) rating indicates that the surfactant failed to wet the smoke, a (w) rating that a weak suspension formed, a (+) rating that a stable suspension formed and a (++) rating means that the suspension was stable for at least one hour.

A total of 90 surfactants of various types (anionic, cationic and nonionic) were evaluated in both the wetting and smoke knockdown studies. The names and classifications of the surfactants are given in the Appendix. Surface tension data were obtained on many of the surfactant solutions by the drop weight method (1, 2).

RESULTS

Wetting Studies

Ratings on the ability of all of the surfactant solutions to wet JP-5 smoke are given in the Appendix. Although most of the surfactants tested formed at least weak suspensions of the smoke in either distilled or salt water, the 17 listed in Table 1 showed superior wetting ability for JP-5 smoke. These included all three types of surfactants: anionic, cationic and nonionic. Some surfactants, for example, Aerosol OS and Triton CF 54 performed better in distilled water than in saltwater, while others (Gafac RE 610, Tritons AH-861, DF-12 and DF-16 and FC-200) were better in saltwater. As shown in Figure 3, some surfactants, e.g., Aerosol OS, formed suspensions that were stable for at least 24 hours. However, no correlation between surface tension and wetting ability of the surfactant solutions was observed.

Smoke Knockdown Studies

All of the surfactant solutions which received (++ or +) ratings in the wetting studies were evaluated for smoke knockdown effectiveness. A plot showing the range in the photomultiplier currents obtained during the smoke knockdown tests is given in Figure 4. The data show that the surfactant solutions definitely knocked down smoke as indicated by the reduction (2 1/2 to 10 fold) in attenuation of the laser beam through the chamber. However, in no case did the surfactant spray completely clear the chamber of smoke. The reason for this failure was that the capacity of the spray system was not sufficient to deal with the large volume of smoke generated by the continuously burning fuel. In general, the surfactants which exhibited superior smoke wetting properties (++ rating in Table 1) performed better in the smoke knockdown tests than the surfactants which merely wetted the smoke (i.e., the surfactants which received a (+) rating in the Appendix). The differences in performance of the various surfactant solutions, as indicated by the range in photomultiplier currents (Figure 4) were not as great as anticipated from the wetting studies.

CONCLUSIONS

Of the 90 surfactants tested, 17 were found to have superior smoke wetting properties and somewhat better smoke knockdown characteristics. The results are sufficiently encouraging to warrant scaling up the tests so that commercial spray equipment can be employed in the smoke knockdown tests.

REFERENCES

(1) W. D. Harkins and F. E. Brown, J. Am. Chem. Soc. 43, 827 (1921).
(2) R. C. Brown and H. McCormick, Phil. Mag. 39, 420 (1948).

TABLE I

Surfactants Showing Superior Ability to Wet JP-5 Smoke

Surfactant*		Type	Rating		Surface Tension (dyne/cm)	
			Distilled Water	Salt Water	Distilled Water	Salt Water
Aerosol	OS	Anionic	++	+	34.7	31.5
Atlas	3300	"	++	n.d.**	28.4	29.0
Gafac	RA 600	"	++	n.d.	n.d.	n.d.
Gafac	RE 610	"	+	++	34.4	34.5
Nacconol	35SL	"	++	n.d.	36.0	n.d.
Triton	AH-861	"	+	++	28.4	28.9
Triton	GR-5	"	++	w	24.6	24.4
Triton	X-180	"	++	++	29.9	29.6
3M	FC-200	Cationic	+	++	16.3	16.4
Igepal	CO 630	Nonionic	++	n.d.	n.d.	n.d.
Renex	36	"	++	n.d.	27.6	n.d.
Triton	CF-32	"	++	w	33.5	34.3
Triton	CF-54	"	++	+	31.5	28.3
Triton	DF-12	"	+	++	32.4	32.0
Triton	DF-16	"	+	++	30.6	30.9
Triton	N-101	"	n.d.	++	n.d.	31.7
Triton	X-100	"	++	++	31.2	31.3

* - All surfactants used as 2% aqueous solutions
**n.d. = not determined due to insufficient sample

APPENDIX

Ratings of Ability of Surfactant Solutions to Wet JP-5 Smoke

		Manufacturer	Rating: Distilled Water	Rating: Salt Water	Surface Tension (dyne/cm): Distilled Water	Surface Tension (dyne/cm): Salt Water
I. Anionic Surfactants						
Aerosol	AY	1	+	+	26.2	25.0
"	BPE	1	+	+	25.8	n.d.*
"	MA	1	w	+	28.9	23.7
"	OS	1	++	+	34.7	31.5
"	OT	1	+	+	25.7	26.0
"	18	1	+	+	n.d.	48.8
Alipal	CO 436	2	+	n.d.	n.d.	n.d.
Alkanol	189-S	3	+	n.d.	n.d.	n.d.
Atlas	2090**	4	+	+	32.2	31.7
"	3300	4	++	w	28.4	29.0
Dowfax	2A1	5	+	n.d.	34.4	n.d.
Duponol	RA	3	+	n.d.	29.9	29.9
Gafac	RA 600	2	++	n.d.	n.d.	n.d.
"	RE 610	2	+	++	34.4	34.5
Igepon	AP 78	2	-	n.d.	n.d.	n.d.
"	T 33	2	+	n.d.	n.d.	n.d.
Nacconol	35 SL	6	++	n.d.	33.9	n.d.
3M	FC-126	7	w	n.d.	21.9	n.d.
"	FC-128	7	+	n.d.	18.8	n.d.
Tergitol	08	8	w	+	n.d.	n.d.
"	4	8	+	n.d.	n.d.	n.d.
"	7	8	w	+	n.d.	n.d.
"	P-28	8	w	n.d.	n.d.	n.d.

*n.d. = not determined due to insufficient sample

** Anionic and Cationic

		Manu-facturer	Rating Distilled Water	Rating Salt Water	Surface Tension (dyne/cm) Distilled Water	Surface Tension (dyne/cm) Salt Water
Triton	AH-861	9	+	++	28.4	28.9
"	GR-5	9	++	w	24.6	24.4
"	H-55	9	w	-	n.d.	51.7
"	H-66	9	+	+	n.d.	39.2
"	X-180	9	++	++	29.9	29.6
"	X-193	9	+	+	n.d.	28.5
"	X-200	9	+	+	n.d.	29.7
"	X-301	9	+	+	n.d.	28.7
II. Cationic Surfactants						
Aerosol	C-61	1	+	n.d.	n.d.	n.d.
"	SP	1	+	n.d.	n.d.	n.d.
Atlas	G-263	4	+	+	36.0	36.2
"	G-271	4	+	+	36.7	36.9
3M	FC-134	7	+	+	16.4	17.0
"	FC-200	7	+	++	16.3	16.4
III. Nonionic Surfactants						
Brij	30	4	+	+	27.5	28.2
"	76	4	-	+	33.3	32.6
Igepal	CO 630	2	++	n.d.	n.d.	n.d.
Igepon	DM 970	2	+	n.d.	n.d.	n.d.
Nacconene	BC 87304	6	+	n.d.	36.0	n.d.
Pluronic	L-72	10	w	n.d.	n.d.	n.d.
"	L-92	10	+	n.d.	n.d.	n.d.
"	P-101	10	w	n.d.	n.d.	n.d.
"	P-103	10	+	n.d.	34.4	n.d.
"	P-104	10	+	n.d.	34.2	n.d.
"	P-105	10	+	n.d.	n.d.	n.d.
Renex	30	4	+	n.d.	29.2	n.d.
"	31	4	+	n.d.	30.9	n.d.
"	36	4	++	n.d.	27.6	n.d.
"	688	4	+	n.d.	31.2	n.d.
"	690	4	+	n.d.	32.2	n.d.
"	698	4	+	n.d.	31.8	n.d.

		Manufacturer	Rating		Surface Tension (dyne/cm)	
			Distilled Water	Salt Water	Distilled Water	Salt Water
Tergitol	15-S-5	8	w	n.d.	n.d.	n.d.
"	15-S-7	8	+	n.d.	n.d.	n.d.
"	15-S-9	8	+	n.d.	29.2	n.d.
"	NP-14	8	w	n.d.	39.6	n.d.
"	NP-27	8	w	n.d.	n.d.	n.d.
"	NP-35	8	+	n.d.	n.d.	n.d.
"	NP-40	8	+	n.d.	n.d.	n.d.
"	NPX	8	+	n.d.	n.d.	n.d.
"	TMN	8	+	n.d.	n.d.	n.d.
"	XD	8	w	n.d.	n.d.	n.d.
"	XH	8	w	n.d.	33.7	n.d.
Triton	CF-32	9	++	w	33.5	34.3
"	CF-54	9	++	+	31.5	28.3
"	CF-76	9	+	+	32.2	31.5
"	DF-12	9	+	++	32.4	32.0
"	DF-16	9	+	++	30.6	30.9
"	N-57	9	+	+	n.d.	29.3
"	N-101	9	n.d.	++	n.d.	31.7
"	X-45	9	+	+	n.d.	30.9
"	X-100	9	++	++	31.2	31.3
"	X-114	9	n.d.	w	n.d.	30.1
"	X-155	9	n.d.	+	n.d.	31.5
"	X-190	9	+	+	28.5	n.d.
"	X-207	9	n.d.	w	n.d.	30.4
"	X-363	9	n.d.	w	n.d.	28.3
Tween	20	4	+	n.d.	n.d.	n.d.
"	21	4	+	n.d.	33.5	33.5
"	40	4	w	n.d.	42.1	n.d.
"	60	4	+	n.d.	44.6	n.d.
"	65	4	w	w	44.6	n.d.
"	80	4	+	+	44.0	n.d.
"	85	4	+	w	39.1	40.4

		Manu-facturer	Rating		Surface Tension (dyne/cm)	
			Distilled Water	Salt Water	Distilled Water	Salt Water
SPAN	20	4	w	-	n.d.	n.d.
"	40	4	-	-	n.d.	n.d.
"	60	4	-	n.d.	n.d.	n.d.
"	80	4	-	n.d.	n.d.	n.d.

1 = American Cyanamid, Stanford, Conn.
2 = GAF Corp., New York, NY
3 = E. I. duPont and Co., Wilmington, Del.
4 = Atlas Chemical Industries, Wilmington, Del.
5 = Dow Chemical Co., Midland, Mich.
6 = Allied Chemical Corp., Morristown, N. J.
7 = 3M Company, St. Paul, Minn.
8 = Union Carbide, New York, NY
9 = Rohm and Haas, Philadelphia, Pa.
10 = Wyandotte Chemical Corp. Wyandotte, Mich.

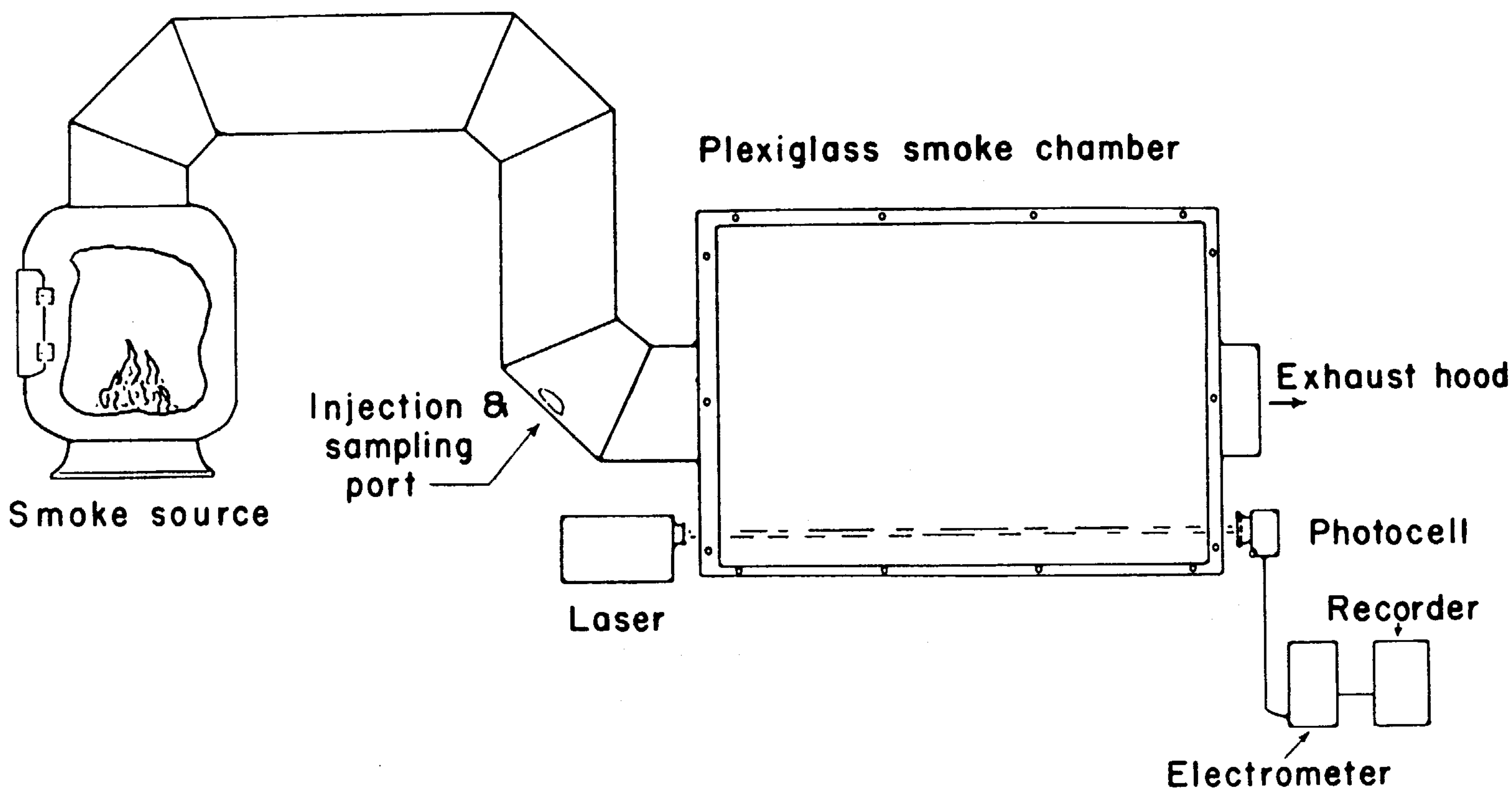

Fig. 1 — Apparatus used in smoke knockdown and wetting studies

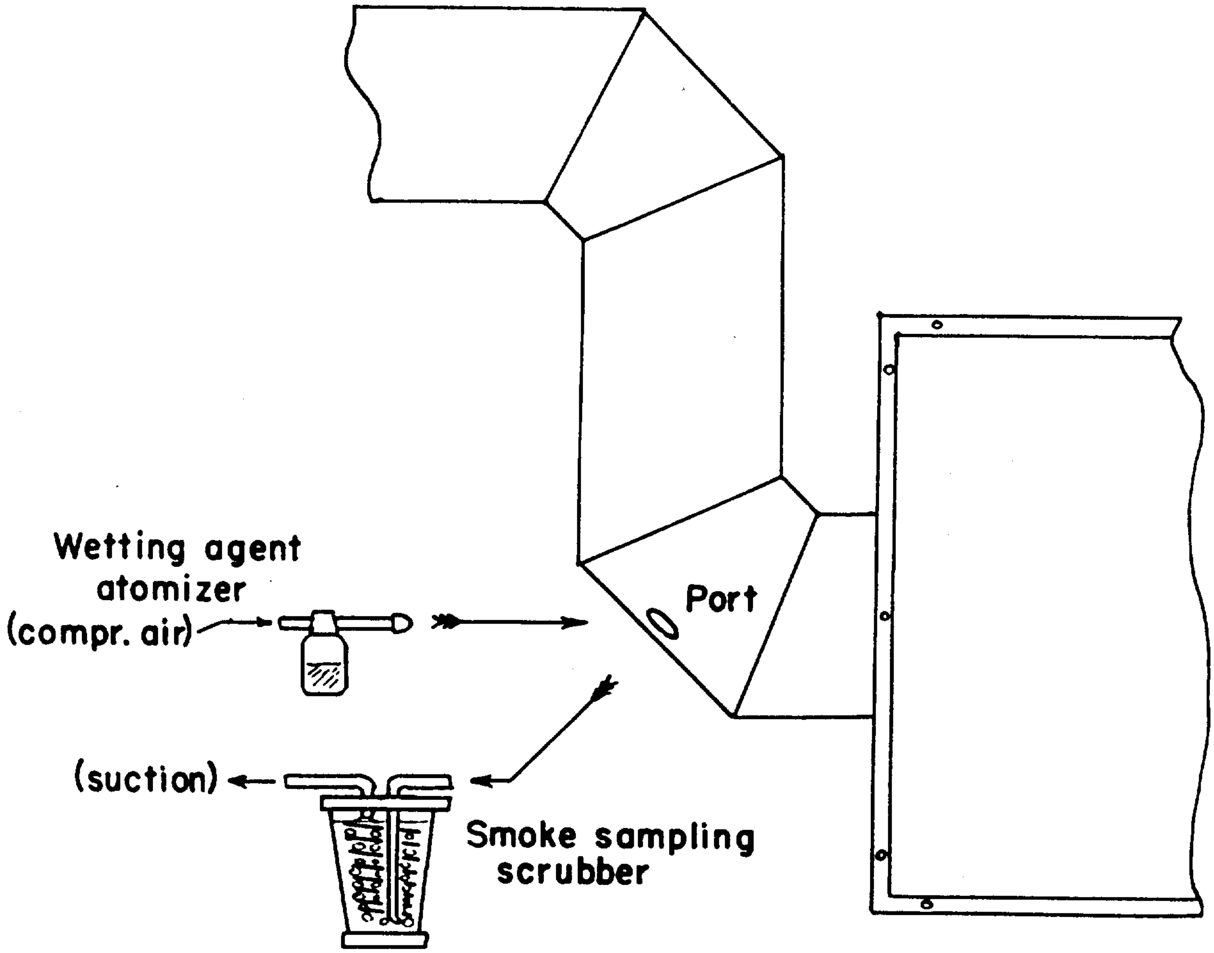

Fig. 2 — Detergent injection and
smoke sampling detail

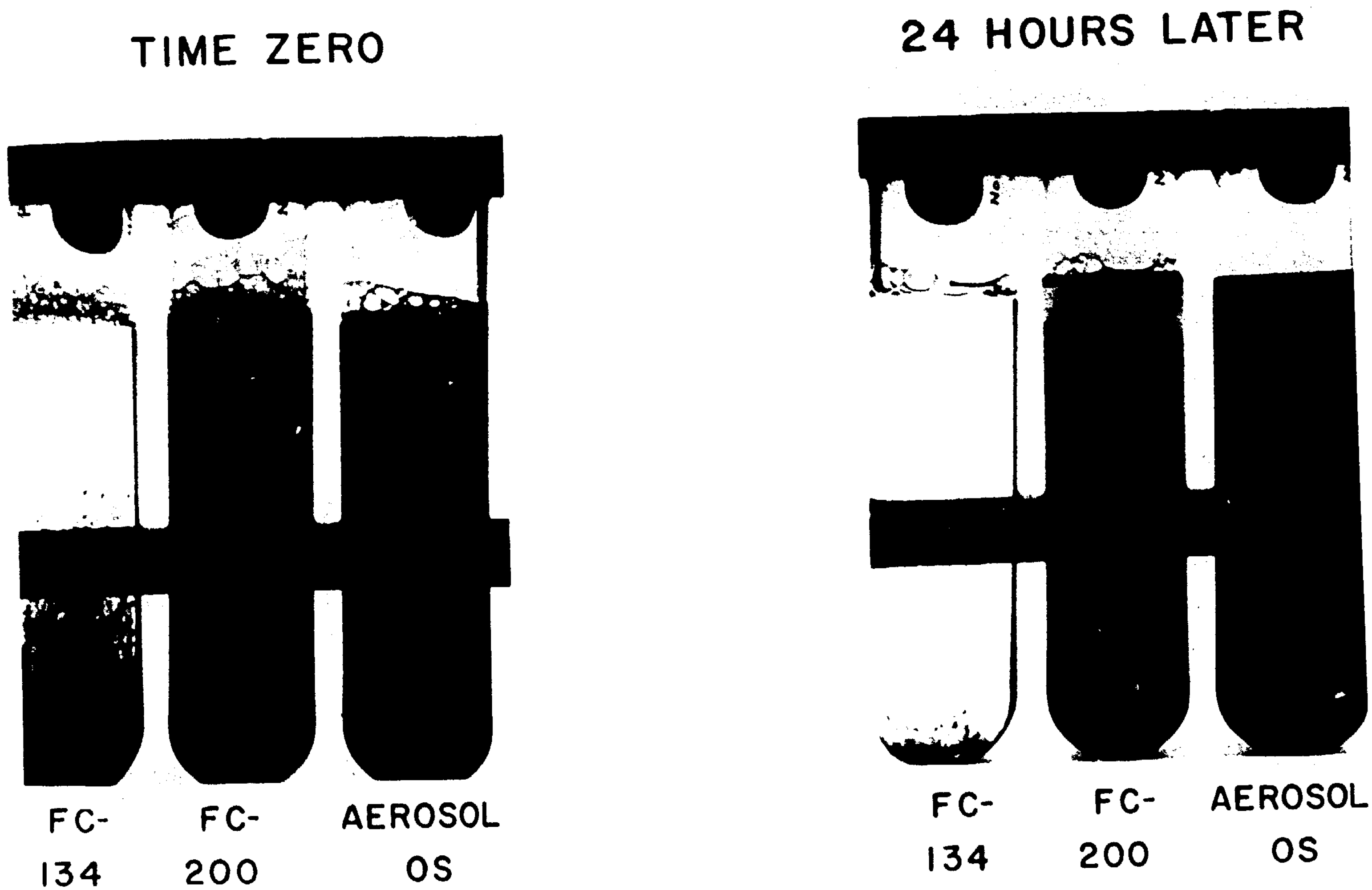

Fig. 3 — Stability of smoke suspensions after standing for 24 hours

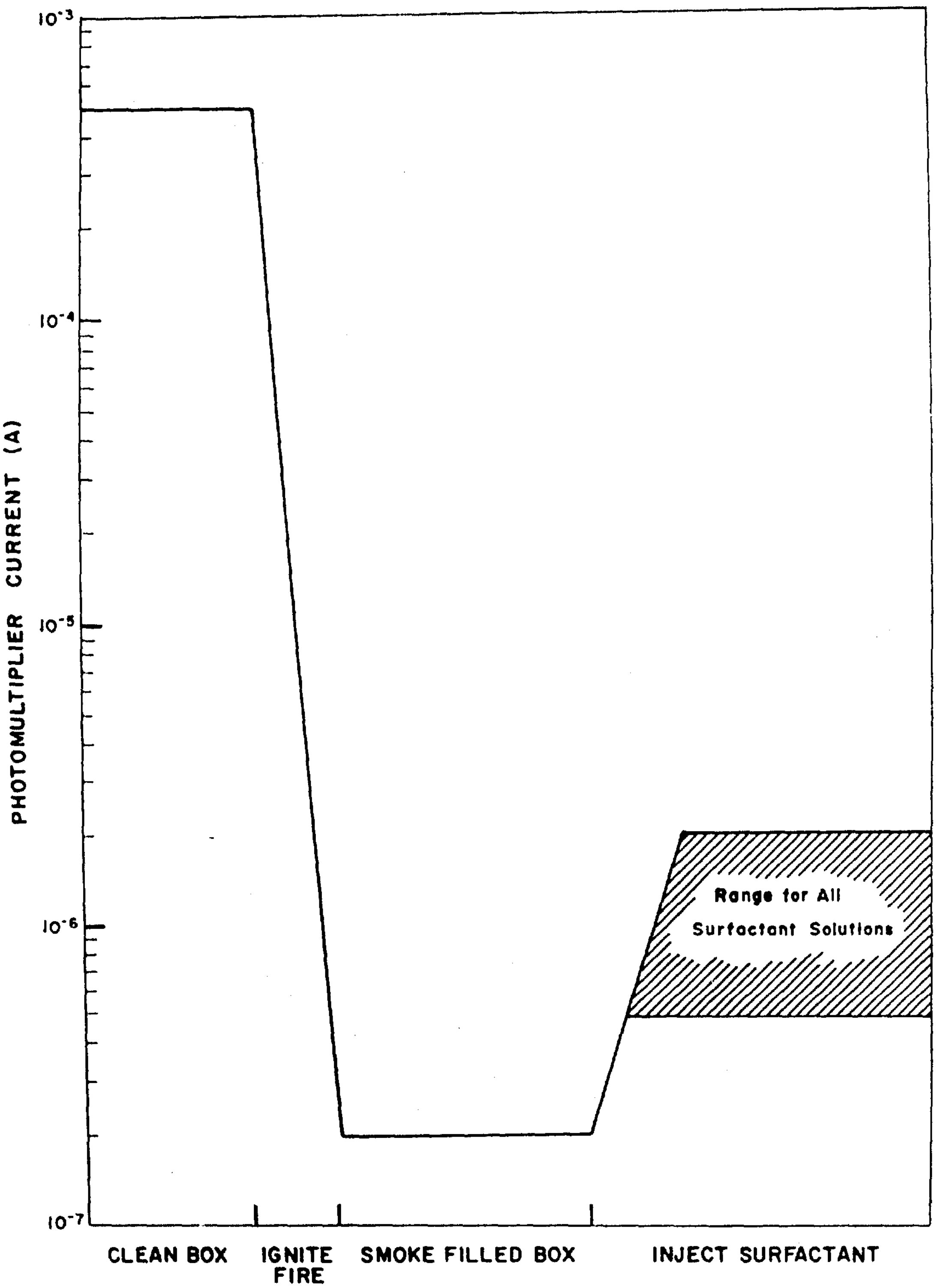

Fig. 4 — Photomultiplier currents during smoke knockdown tests